Pergamon

Computers Math. Applic. Vol. 34, No. 7/8, pp. xiii–xvi, 1997

0898-1221/97 $17.00 + 0.00

PII: S0898-1221(97)00147-8

Preface

Complex systems have introduced a new perspective into the natural sciences and lead to great challenges for computational methods and information technology. Complexity, self-organization, chaos, and resonances are the key features for all realistic systems. These features demand new computational tools for information processing in unstable systems. Brussels/Austin groups have played a pioneering role in the development of certain basic concepts of the theory of complex systems and have introduced new computational tools for unstable systems based on probabilistic and functional methods for the treatment of resonances and instabilities. Complex systems are manifestly irreversible. The consistent formulation of irreversible processes was the focus of activity of the Brussels/Austin groups during the last 30 years. Irreversibility and complex systems analysis was the common interest of those who contributed in this edition.

The work presented here is the result of the activity of the Brussels/Austin groups and the groups sharing the same interests. A significant part of the contributions was reported at the Workshop on Computational Tools for Complex Systems held at the International Solvay Institutes for Physics and Chemistry in Brussels on May 2–4, 1995. This workshop was organized in the frame of the Euro-Russia Collaboration Project financed by the European Commission, DG III, ESPRIT Project 9282 "Algorithms and Computational Tools for Complex Systems". This collaboration involves the International Solvay Institutes and four Russian Institutes, namely the International Research Institute of Management of the Russian Academy of Sciences in Moscow, the Laboratory of Complex Systems Theory in the St. Petersburg State University, the Institute of Applied Physics of the Russian Academy of Science in Nizhny Novgorod and the Research Institute for Applied Mathematics and Cybernetics in Nizhny Novgorod.

We have grouped the contributions into three parts.

PART I. DYNAMICAL SYSTEMS, CHAOS, AND CONTROL

This part is devoted to dynamical systems, chaos, and control.

The first three papers discuss Hamiltonian systems. Petrosky and Prigogine (I.1) presented the extension of dynamics for Hamiltonian systems with Poincaré resonances. Poincaré nonintegrable systems manifest intrinsically irreversible behavior. Poincaré initiated the study of these systems with the famous 3-body problem by the end of 19$^{\text{th}}$ Century. This example posed the problem of integrability and chaos and was a landmark of the study of unstable systems. Akishin, Puzynin and Vinitsky (I.2) proposed a new numerical method for the analysis of classical unstable systems. Dmitrieva and Khlabystova (I.3) presented a scheme for the construction of soliton solutions for a complex infinite-dimensional Hamiltonian system.

The following three papers discuss chaotic maps. The original probabilistic analysis for Poincaré systems introduced by the Brussels/Austin groups has been applied for these systems and new spectral decomposition including the resonances have been constructed. The paper by Bandtlow, Antoniou and Suchanecki (I.4) demonstrated that the class of operators admitting spectral decompositions in rigged Hilbert spaces which include the resonances of the power spectrum, are the Fredholm-Riesz operators. Driebe (I.5) demonstrates for the first time, through a simple Markov map, that exact endomorphisms may have Jordan block decomposition. Gonchenko,

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Shil'nikov, Sten'kin and Turaev (I.6) studied bifurcations of diffeomorphisms with structurally unstable homoclinic orbits.

The following six papers discuss dissipative differential equations. Pokrovski (I.7) studied the scattering of sound waves by thin infinite elastic planes in terms of Lax-Phillips theory. He gives an operator theoretic treatment of the well-known head waves and of the continuous spectrum of resonances which appear. Shil'nikov and Turaev (I.8) resolved the problem of "blue sky catastrophe" in a general one-parameter family of ordinary differential equations. The next two papers are devoted to quasiattractors. Gonchenko, Shil'nikov and Turaev (I.9) studied quasiattractors and homoclinic tangencies. Bykov (I.10) investigated a mechanism for the appearance of a spiral quasiattractor involving heteroclinic contours. Shil'nikov (I.11) discussed homoclinic phenomena in laser models and describes the principal bifurcations which lead to the Lorentz attractor. Belyakov, Glebsky and Lerman (I.12) found stationary localized solutions to the Swift-Hohenberg pattern forming gradient system. Arutyunov, Bobylev and Korovin (I.13) generalized Ekeland's variational principle to include second-order conditions.

The last seven papers are devoted to the stabilization and control of chaotic systems. Emelyanov and Korovin (I.14) presented their theory of nonlinear feedback under uncertainty. Their methods find applications in the stabilization of uncertain plants. Kirichenko (I.15) proposed a method for estimating domains with limit cycles, while Babloyantz, Bobylev, Korovin and Nosov (I.16) showed how to approximate unstable cycles in nonlinear autonomous systems. Babloyantz, Kirichenko and Nosov (I.17) proposed a technique for nonlinear control and stabilization of unstable periodic orbits of chaotic systems and apply their technique to the Lorentz and Rössler systems. Magnitskii (I.18) presented a simple method for the location and stabilization of unstable periodic orbits of chaotic maps. Antoniou, Basios and Bosco (I.19) introduced a probabilistic approach for the control of chaotic systems based on the spectral decomposition developed by the Brussels/Austin groups. Willox, Antoniou and Levitan (I.20) show that parametric partial control of chaotic billiards is possible.

PART II. QUANTUM SYSTEMS AND OPERATORS

This part is devoted to quantum systems and operators.

The first eight papers deal with resonances. Antoniou, Dmitrieva, Kuperin and Melnikov (II.1) introduced an operator theoretic treatment of resonance states in rigged Hilbert space which is a synthesis and generalization of the Brussels/Austin approach, the Bohm/Gadella approach, and the St. Petersburg approach to resonances. Their method is illustrated by three prototypes of complex systems. Bohm, Gadella and Maxson (II.2) propose an intrinsically irreversible extension of quantum theory for scattering resonances in terms of rigged Hilbert spaces. Gustafson (II.3) gave a formulation of irreversible extensions of operators for unstable systems in terms of a regularity principle and characterizes the operator extension in terms of state diagrams. Antoniou and Suchanecki (II.4) characterized the algebra and the logic of quantum systems with diagonal singularities. These systems include the quantum Poincaré nonintegrable systems, which manifest intrinsic irreversibility. Rosenberg and Petrosky (II.5) studied microscopic nonequilibrium structures and entropy in quantum fields using the complex spectral method developed by the Brussels/Austin groups. Kuperin, Levin, Melnikov and Yarevsky (II.6) applied the extension theory of the St. Petersburg group to antiproton-nucleon systems with a continuous set of resonances. Their predictions coincide with experimental data with better accuracy than the conventional approaches. Dmitrieva, Kuperin and Rudin (II.7) studied the one-dimensional quantum three-body problem and reduced the problem of integrability to the integrability of the extended Dubrovin's equations. Romanov and Rudin (II.8) studied the scattering resonances on p-adic graphs. This type of scattering is a prototype of scattering on fractal structures.

The next two papers are devoted to study of the spectral properties of the quantum Lorentz gas. Kuperin, Levin, Melnikov and Pavlov (II.9) derived the basic integral equation on the boundary of hard discs and show that the spectrum of the system has the band structure. Akishin, Bosco and Vinitsky (II.10) developed a new algorithm for the numerical study of the spectral properties of the quantum Lorentz gas.

The last three papers deal with the study of different types of spectral problems. Antoniou and Il'in (II.11) derived the uniform estimates for the spectral functions and consider the Fourier integral expansion for the one-dimensional Schrödinger operator with a periodic potential. Il'in and Kritskov (II.12) proved uniform convergence of the spectral expansions for the one-dimensional Stark effect Hamiltonian. Il'in (II.13) showed how to express basis condition and uniform convergence of expansions related to nonselfadjoint differential operators. Moiseev (II.14) studied spectral characteristics of some nonlocal boundary-value problems for the Laplace operator on a two-dimensional disk.

PART III. COMPUTATIONAL TOOLS AND APPLICATIONS

This part is devoted to certain computational tools and applications to selected complex systems.

The first four papers study different types of neural networks. Mardanov, Pismak and Potyagailo (III.1) studied the general properties of realistic neural networks introduced by Kropotov and clarified the role of symmetry in the dynamics of realistic neural networks. Ivanov, Itkis, Purevdorj, Puzynin and Vinitsky (III.2) found new regimes in the realistic neural networks, such as inertia, sweeping, and depression. Bonushkina, Ivanov and Zrelov (III.3) studied multidimensional classifiers based on the goodness-of-fit criteria and multilayer perceptron. Basios, Bonushkina and Ivanov (III.4) presented a new method for the approximation of one-dimensional functions based on the application of the artificial feedforward neural network.

DISTO collaborators (III.5) have applied a cellular automaton for the recognition of straight tracks on the spectrometer DISTO. Their program has demonstrated high efficiency and speed.

Ivanov and Zrelov (III.6) studied the properties and applications of nonparametric integral statistics.

The remaining papers are devoted to various applications of light-matter interactions. Kocharovskys, Derishev, Litvak, Shereshevsky and Tasaki (III.7) applied the complex spectral analysis developed by the Brussels/Austin groups to the study of nonadiabatic crossing of decaying levels. The next two papers are devoted to superradiance phenomena in atomic physics. Antoniou, Kocharovskys, Mironov and Shereshevsky (III.8) studied absolute and convective superradiance, namely, the dynamics and microscopic quantum fluctuations. Kocharovskys and Golubyatnikova (III.9) studied mode instability and nonlinear superradiance phenomena in the open Fabry-Perrot resonator. Kocharovskys and Belyanin (III.10) studied inhibited spontaneous emission and electromagnetic instability of an atom in the near zone from the surface of an active medium. Kocharovskys, Kokyshkin, Mironov and Zaitsev (III.11) studied the effects of the spatial dispersion and instabilities in weakly ionized gases. Belyanin and Kocharovskys (III.12) studied cooperative coherent phenomena in annihilating electron-positron and electron-hole plasmas in a strong magnetic field. Melnikov, Derbov, Vesheva and Konukhov (III.13) performed numerical studies of beam and pulse propagation in lasers and nonlinear media. Mardanov, Pismak and Rappoport (III.14) studied the interaction of ultra-violet radiation with one-chain pyramidine polynucleotides. They introduced mathematical models of the process and predicted that a certain concentration of dimers in polynucleotides can protect polynucleotides from ultra-violet radiation.

We would like to express our gratitude to all the contributors who worked hard for the project. We would like also to thank in particular Mr. Solvay and Prof. G. Nicolis for their support and encouragement. The assistance of Drs. V. Basios, F. Bosco, L. Dmitrieva and Yu. Melnikov as well as of A.-C. Blondlet, M. Kies, M. Klein and M. Kuneben was essential for the success of the project and the workshop. Finally we would like to acknowledge the support of the European

Commission without which this special issue would be impossible. In particular, we thank the Director G. Metakides, as well as T. Van der Pyl, B. Hawdon, S. Rogers and P. Van Hove for their advice and support during the different stages of the Collaboration Project.

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Guest Editors